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New E-Learning opportunities based Artificial Neural Networks for Mobility impairments

Salim M. Hussein Al-Wasity

Assistant Lecturer

College of Engineering- Wasit University

Abstract

E-learning is becoming globally widespread and more common. The usefulness of interactive systems in e-learning lies not in performing the processing task itself but in communicating requests and results between the system and its user. Therefor the E-Learning can offer great chances to students with disabilities that can access its application through an alternative channel using Human- Computer interaction (HCI) methods. This paper tries to review the various methods of (HCI) used for mobility disabilities and implement one of these methods using Electrooculography (EOG) signals to write using a virtual keyboard.

Introduction

HCI deals with perception, interaction and accessibility as core issues, but in the last years new challenge are appear to re-thinking and expanding the educational approaches in this area to start a new era of E-learning based (HCI) for physical disabilities that have many types such as mobility, visual, and hearing impairments. [1].

1. E-learning

The American Society of Training and Education (ASTE) define the Digital Learning or E-learning as: "E-learning is the application of digital media by the learner in the learning process, where digital media includes the Internet, corporate networks, computers, satellite broadcasts, audio tapes, videos, interactive television, and CD-ROMs, etc. The scope of E-learning applications includes online learning, computerized learning, virtual classrooms, and digital cooperation" [2]. And it is define as "E-Learning is an ideal learning environment using modern means of information technology, through the effective integration of information technology and the curriculum to achieve, a new learning style which can fully reflect the main role of the students to thoroughly reform the traditional teaching structure and the essence of education, to train large numbers of high quality personnel [3]. E-learning has changed the traditional teaching structure and the nature of education, and made up for deficiencies in space-time separation, The E-learning comes in may form such as [4]:

- **Standalone courses**. Courses taken by a solo learner. Self-paced without interaction with an instructor or classmates
- **Virtual-classroom courses**. Online class structured much like a classroom course. May or may not include synchronous online meetings
- **Learning games and simulations**. Learning by performing simulated activities that require exploration and lead to discoveries.
- **Embedded e-learning**. E-learning included in another system, such as a computer program, a diagnostic procedure, or online Help.
- **Blended learning**. Use of various forms of learning to accomplish a single goal. May mix classroom and

e-learning or various forms of e-learning.

- **Mobile learning**. Learning from the world while moving about in the world. Aided by mobile devices such as PDAs and smart phones.
- **Knowledge management**. Broad uses of e-learning, online documents, and conventional media to educate entire populations and organizations rather than just individuals.

This paper represented an example of an embedded E-learning. Recently E-learning has been going through new transformations into what is referred to as E-learning 2.0, with reference to Web 2.0. The drive behind this change is the shift in education from being tutor-centered to becoming more learner-centered [5]. The E-learning have advantages and disadvantages as listed below:

I. Advantages of E-learning

The key advantages of E-learning are [6]:

- Flexibility, convenience and the ability to study at one’s own pace at any time and any place where an internet connection is available.
- Ability to chat and exchange information over Internet with fellow classmates independent of metric distance, a greater adaptability to learner's needs, more variety in learning experience with the use of multimedia and the nonverbal presentation of teaching material.

II. Disadvantages of E-learning

Like any learning methods, the E-learning have many disadvantage points such as [6]:

- Educational related disadvantages: one disadvantage of e-learning is the lack of face-to-face interaction.
- Social/cultural and economic related disadvantages: a non-educational disadvantage is that web and software development can be expensive.
- Long lasting limitations: E-learning portals in general have been designed for “ordinary users” although this group consists of users with large differences in knowledge and skills of using computers and the Web. They have also different skills in using the keyboard.
- Cheating: cheating offers an easy way out.

2. Mobility Impairments [7]

The Mobility impairment refers to the inability of a person to use one or more of his/her extremities, or a lack of strength to walk, grasp, or lift objects. The use of a wheelchair, crutches, or a walker may be utilized to aid in mobility. Some mobility impairments are caused by conditions present at birth while others are the result of illness or physical injury. Injuries cause different types of mobility impairments, depending on what area of the spine is affected.

A few types of mobility impairments are listed below:

- **Spinal Cord Injuries**: often occur during the young adult years and usually result in full or partial paralysis.
- **Cerebral Palsy**: it is a chronic condition characterized by difficulty in controlling and coordinating voluntary muscle movements.
- **Paralysis**: loosing feeling in certain parts of the body and not be able to move these parts of the body.
- **Hemiplegia**: is the paralysis of one side of the body as a result of a stroke or traumatic brain injury and should not be confused with paraplegia or quadriplegia. With quadriplegia and paraplegia the brain is not affected. With hemiplegia, there may be an impairment of intellect, personality, speech or senses.

- **Paraplegic**: the paralysis of the lower extremities and part or all of the trunk muscles.
- **Quadriplegia**: occurs when there is damage to the spinal cord in the Cervical Region. This will cause impairment to the hands and arms in addition to the effects of paraplegia.
- **Multiple Sclerosis:** a disorder of the nervous system that attacks the brain and spinal cord and causes deterioration of the nerve tissue.
- **Polio**: a disease that kills nerve tissue in the spinal cord, which causes a high fever, paralysis of different muscles.
- **Muscular Dystrophy**: is a disease in which the muscles of the body get weaker and weaker and slowly stop working.

Human Computer Interaction (HCI)

It is the study of interaction between users and computers. It is often regarded as the intersection of computer science, behavioral sciences, design and several other fields of study. The Association for Computing Machinery defines HCI as *"a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."* [8].

An important facet of HCI is the securing of user satisfaction. A basic goal of HCI is to improve the interactions between users and computers by making computers more usable and receptive to the user's needs. Specifically, HCI is concerned with:

- Methodologies and processes for designing interfaces
- Methods for implementing interfaces
- Techniques for evaluating and comparing interfaces
- Developing new interfaces and interaction techniques

A long-term goal of HCI is to design systems that minimize the barrier between the human's cognitive model of what they want to accomplish and the computer understands of the user's task [8].

The most popular subset of HCI is the Brain Computer Interface (BCI) systems which use as input not only cerebral signals but also other electrophysiological signals such as Electrooculography (EOG) and Electromyography (EMG) [9]. Most of the existing BCIs are based on the synchronous experimental protocol in which the subject must follow a fixed repetitive scheme to switch from one mental task to the next. The other BCIs rely on more flexible asynchronous protocol where the subject makes self-paced decisions on when to stop doing a mental task and start the next one [10]. There are two types of (BCI) systems, based on the acquisition of neurophysiological signals:

- **Direct Brain Computer Interface**
  Direct BCIs involve invasive procedure to implant electrodes in the brain [10]. Thus the signals acquired from single or small groups of neurons used to control the (BCI). In most cases the most suitable option for placing the electrodes is the motor cortex region, because of its direct relevance to motor tasks [11].
- **Non-invasive Brain Computer Interface**
  Non-invasive BCIs are based on the analysis of EEG phenomena associated with various aspects of brain function [10]. These EEG phenomena are acquired through macro electrodes covering the scalp.

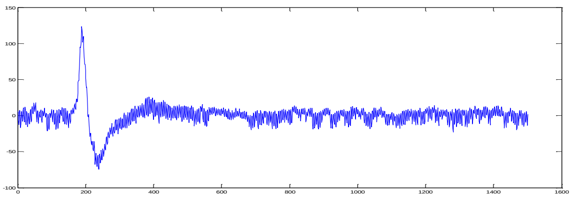
Electroencephalography (EEG)

The Electroencephalography (EEG) is a medical technique that measures the electrical activity of the brain. This activity is generated by billions of neurons, and each one is connected to thousands of other neurons [12].

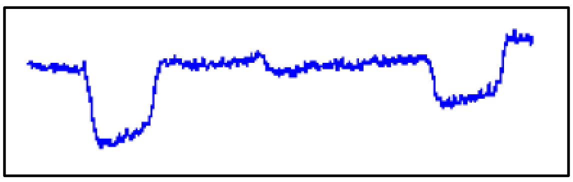
The EEG signals are complex spatiotemporal signals. The statistical properties of which depend on the state of the subject and on external factors, even when the subject behavioral state is almost constant. The duration of epochs that have the same statistical properties (i.e. that are stationary) is limited. Therefore EEG signals present essential non-stationary properties [12]. The temporal resolution of EEG signals is very good, in millisecond or even better. While the spatial resolution is poor, it depends on the number of electrodes, about in centimeter range [13].

Eye Blinks

A communication interface controlled by eye movements and voluntary eye blink has been developed for disabled individuals who have motor paralysis and therefore cannot speak [14]. The Eye blinks and eye movements are consider as artifacts that contaminate the Electroencephalography (EEG) data at any time of the recording process [15]. Figure (1) shows an example of an EEG signal contain (a) eye blinking, and (b) eye movement. The EEG contains the technical artifacts (noise from the electric power source, amplitude artifact, etc.) and biological artifacts (eye artifacts, ECG and EMG artifacts) [16].



(**a**)



(**b**)

Figure (1) EEG signal contain: (**a**) A clean eye blink artifacts, (**b**) A clean eye Movement artifacts

Windowed-Sinc FIR Filters [17]

Windowed-sinc FIR filters are used to separate one band of frequencies from another. They are very stable, produce few surprises and can pushed to incredible performance levels. The pass-band is perfectly flat, the attenuation in the stop-band is infinite, and the transition between the two is infinitesimally small. The idea of the windowed-sinc filter is to convolving the input signal with the filter kernel (impulse response of the filter). The filter kernel is obtained by taking the inverse Fourier transform of the ideal frequency response of the low-pass filter, which produces the ideal filter kernel as shown in Fig. (2), the form of this kernel is called sinc function, given by

$$h[i] = \frac{\sin(2\pi f_c i}{i\pi} \qquad (1)$$

Where ***h[i]*** is the filter kernel

f_c is the cutoff frequency as a ration to the sampling rate, and

i is the index

The Sinc function continues to both negative and positive infinity without dropping to zero amplitude, so to overcome this problem the sinc function will be modified by truncated the kernel of the filter to M+1 point symmetrically around the main lobe, and to multiply the truncated sinc function by a smoothly tapered curve called Blackman or Hamming windows resulting the windowed-sinc filter kernel, and these windows are gives respectively by:

$$w[i] = 0.54 - 0.46\cos(2\pi i / M) \qquad (2)$$

$$w[i] = 0.42 - 0.5\cos(2\pi i / M) + 0.08\cos(4\pi i / M)$$
(3)

where ***w[i]*** is window kernel.

M is the length of the filter kernel, and

i is the index.

The idea of improving the frequency response is by reducing the abruptness of the truncated ends of the filter kernel as shown in Fig. (3)

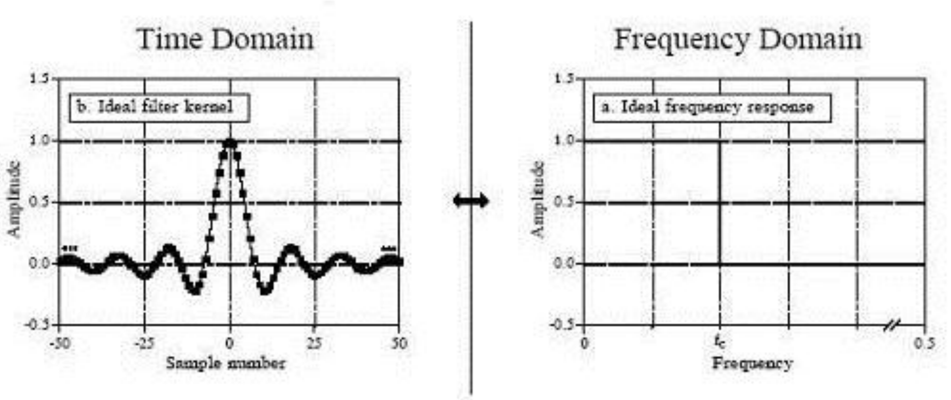


Figure (2): The frequency and impulse response of the low-pass filter

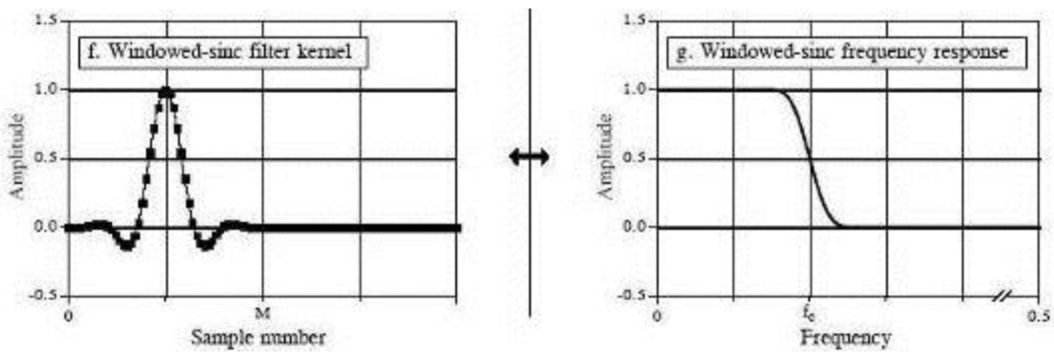
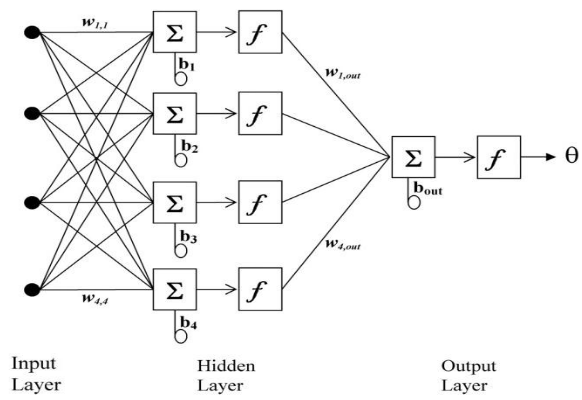


Figure (3): The frequency and impulse response of the windowed-sinc low-pass filter.

Backpropagation algorithm [18], [19]

The most popular class of multilayer feed-forward networks is multilayer perceptron's in which each computational unit employs either the threshold function or the sigmoid function as shown in Fig. (5). Multilayer perceptron's can form arbitrarily complex decision boundaries and represent any Boolean function. The development of backpropagation learning algorithm for determining weights in a multilayer perceptron has made these networks the most popular among researchers and users of neural networks. The standard backpropagation algorithm for training the Multilayer Perceptron Neural Network (MLP NN) is based on the steepest descent gradient approach applied to the minimization of an energy function representing the instantaneous error.



Input Layer ;ure (5): An example of two layer feed forward multilayer perceptron neural network

Training the (MLP NN) by using backpropagation algorithm can be performed according to the following algorithm:

- Initialize the network synaptic weight to small random values.

- From the set of training input/output pairs, present an input pattern and calculate the network response.
- The desire network response is compared with the actual output of the network, and by using the below equations all local errors can by computed
  For output layer

$$\delta_j^{(s)} = \left(d_{qh} - x_{out\,j}^{(s)}\right) g\left(v_j^{(s)}\right) \qquad (4)$$

Where $s=1,2,3$ is the network layer
δ is local error for the jth neuron of the sth layer
j is the neuron index
d_{qh} is the desire output of the hth neuron in the output layer to the qth training input
x_{outj} is the actual network output due to qth training pattern
$g()$ is the derivative of activation function $f()$
$v = \boldsymbol{Wx}$

For the hidden layer

$$\delta_j^{(s)} = \left(\sum_{h=1}^{n_{s+1}} \delta_h^{(s+1)} w_{hj}^{(s+1)}\right) g\left(v_j^{(s)}\right) \quad (5)$$

- The weights of the network are updated as below

$$w_{ji}^{(s)}(k+1) = w_{ji}^{(s)}(k) + \mu^{(s)} \delta_j^{(s)} x_{out.i}^{(s-1)} \quad (6)$$

Where μ is the learning parameter
δ is the local error for jth neuron of sth layer
k is the iteration index.

- Until the network reaches a predetermined level of accuracy in producing the adequate response for all the training patterns, continue steps 2 through 4.

The other backpropagation training algorithm is the Levenberg-Marquardt algorithm which is represents a simplified version of Newton's method that has a numerical optimization technique with quadratic speed of convergence. The Levenberg-Marquardt backpropagation training algorithm can perform as below:

- Initialize the network weights to small random values.
- Present an input pattern, and calculate the output network.
- By using the equation below to calculate the elements of the Jacobian matrix associated with the input/output pairs.

$$J_{i,j} \approx \frac{\Delta e_i}{\Delta w_j} \qquad (7)$$

Where $J_{i,j}$ is the Jacobian Matrix.
Δe_i is the change in the output error due to the small perturbation of the Δw_j

- When the last input/output pair is presented, the weights update are preformed according to:

$$w(k+1) = w(k) - [J_k^T J_k + \mu_k I]^{-1} J_k^T e_k \quad (8)$$

- Stop if the network has converged; else go back to step 2.

The proposed Electrooculography (EOG) control system

This proposed system is intended to develop an EOG communication control system that using the eyes blink which is extracted from EEG signals to control the selection of a letter key on screen virtual keyboard by using the voluntary eyes blink twice as double click and a voluntary eyes blink once as a conformation to that selection (visual feedback). The block diagram of EOG system is shown in Fig. (6).

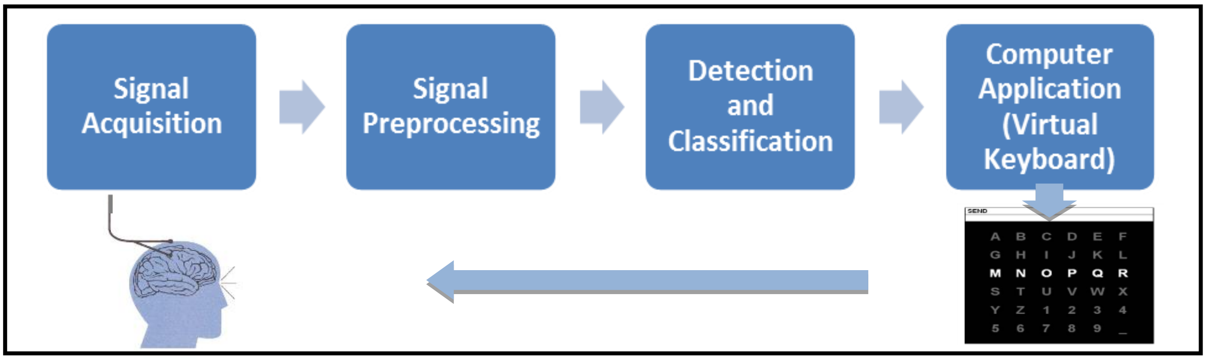


Figure (6): The block diagram of EOG control system

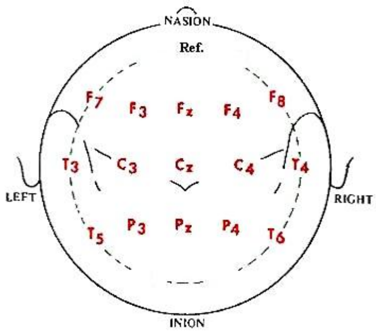
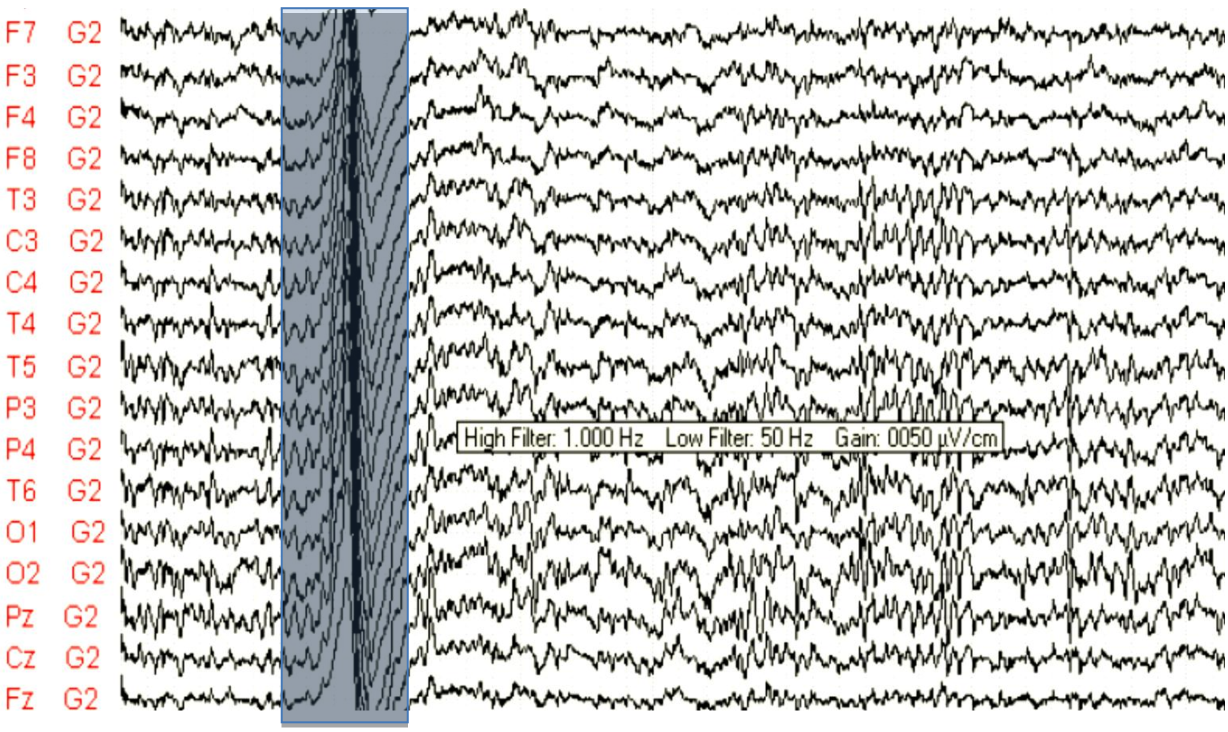


Figure (7): The configuration of scalp electrodes based on the international 10-20 system.

1. Signal acquisition and preprocessing

The EEG signals were measured and recorded using a computerized EEG device in Ibn-Rushid Hospital. These signals are saved as a database for further processing. The whole scalp was covered with 19 electrodes according to the 10-20 international system, and referenced against forehead as shown in Fig. (7), the recorded signals were digitized at 256 Hz according to the specification of the computerized EEG device as shown in Fig. (8).



The recording procedure consists of several sessions each session divided into trial used for training and offline testing, these trails contains the voluntary eyes blink. The EEG signals must be prepared in such a way that the classifier can recognize it. This preparation is made offline to remove other artifacts by using an FIR Band-Pass filter to the electrodes (F3, and F4) of EEG recording. The FIR Band-Pass filter is constructed from convolving the kernels of the low-pass and high-pass filters. A (1-10) Hz band-pass filter is implemented using a Windowed-Sinc FIR filter with a sampling rate of 256 sample/sec., and filter kernel length M of 1024, and a Blackman window has been used in this implementation; therefore the filter kernel of the low-pass filter is calculated as shown below

$$h[i] = K\frac{\sin(2\pi f_c(i - M/2))}{i - M/2}\left[0.42 - 0.5\cos\left(\frac{2\pi i}{M}\right) + 0.08\cos\left(\frac{4\pi i}{M}\right)\right] \quad (7)$$

Where ***h[i]*** is the filter kernel,

K is the filter gain,

M is the length of filter kernel,

fc is the cutoff frequency as a ratio to the sampling rate.

i is the index.

Figure (9) shows an eye blink of F3 electrode before and after filter it by a band-pass filter of (1-10) Hz:

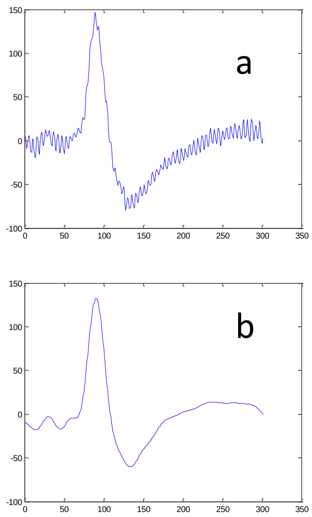


Figure (9): (a) the original eye blink signal of F3 electrode, (b) the filtered signal

2. Training and Recognition

The Multilayer feed-forward network architecture is made up of one hidden layer with 200 neurons of log-sigmoid transfer function, and an output layer of one neuron with bipolar binary transfer function. Input patterns consist of two signal streams represented F3 and F4 signals respectively, are used as a training vector to train the Neural network using the standard and Levenberg-Marquardt training algorithms. The training vector consist of 20 sub trial of eye blink, the remaining trial of eye blink patterns are used for offline testing to generate the control signal that used for key selection.

3. Computer Application

There is a wide range of applications for disabilities depending to the types of there disability such as control the mouse cursor, wheelchair, and virtual keyboard. In this paper an on screen virtual keyboard is proposed to be used. The signal generated from the ANN is used to select one letter from a continuous sliding on screen letters by blink the sys twice, after that confirm this selection by blink the eyes once otherwise the selected letter will cancelled as shown in fig. (10) below:

Figure (10): the on screen virtual keyboard

Results

The training vectors and the desire output signal that shown in Fig. (11) are applied the MLP NN. The MLP NN was trained using the standard and Leven berg-Marquardt training algorithms, after several iterations the outputs of the MLP NN are shown in Fig. (12).

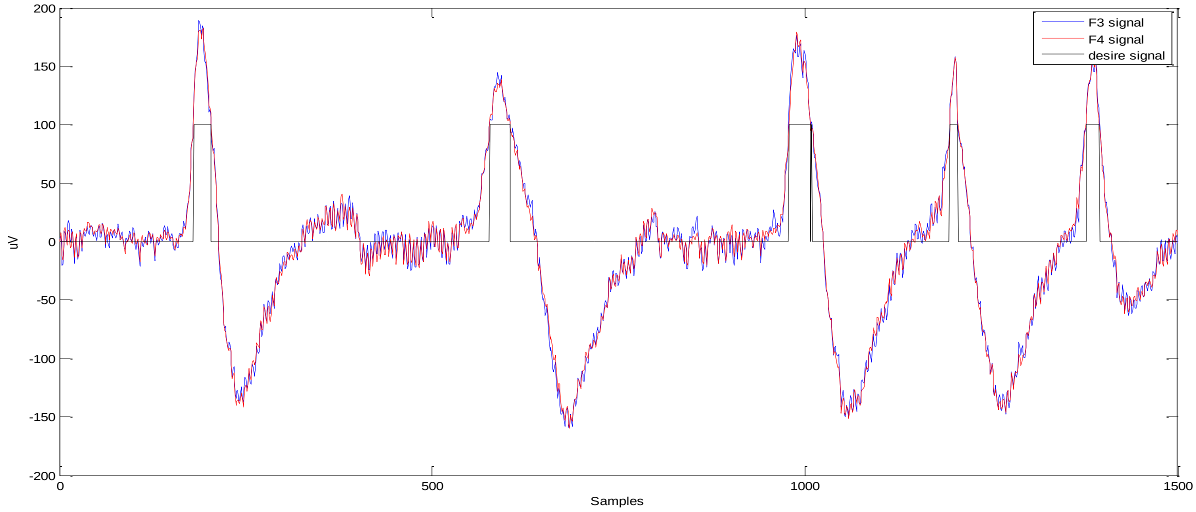


Figure (11): The F3, F4 and Desire signals used for training the MLP NN

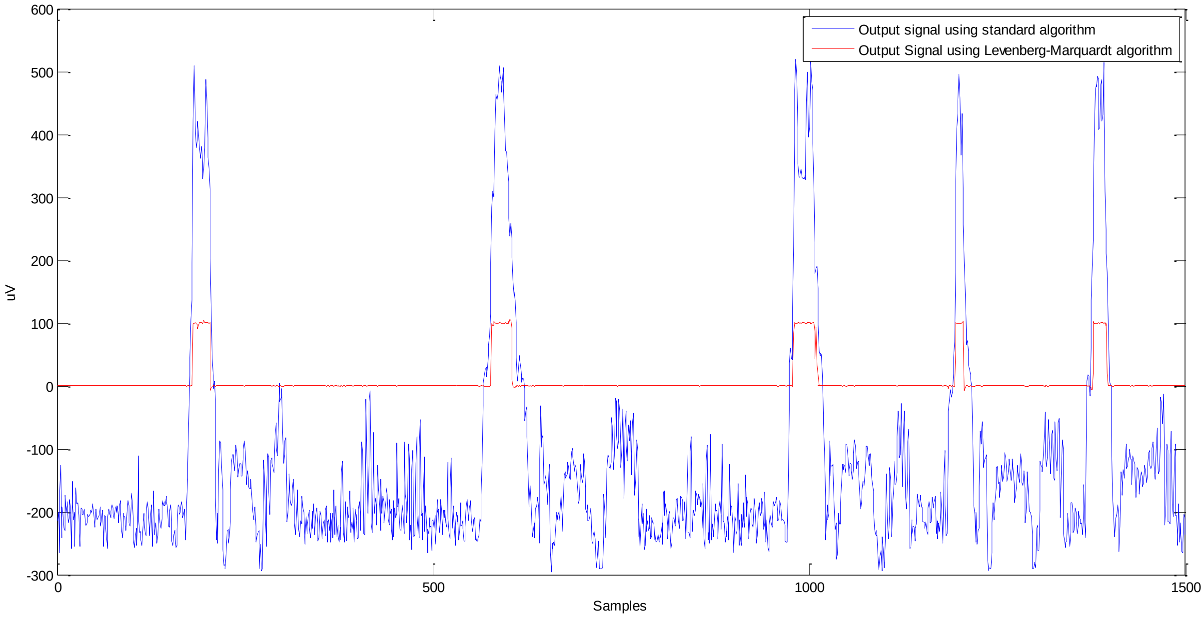


Figure (12): The output signal of MLP NN using standard and Levenberg-Marquardt training algorithms.

Comparison of training algorithms

When compare between the standard and Levenberg- Marquardt training algorithm, the best performance is obtain by using the Levenberg- Marquardt algorithm in the same type of network topology of two input, one hidden layer of 200 neuron, and one output neuron (2 : 200 : 1). Table (1) shows the result after several iterations.

Table (1): The Recognition rate of MLP NN

Training Algorithms	Recognition Rate	Epoch
Standard Algorithm	71%	6
Levenberg Marquardt Algorithm	96%	45

Conclusion

This paper presents a new application of using MLP NN to detect the eye blink artifacts in EEG signal of F3, and F4 electrodes. The Standard and Levenberg-Marquardt backpropagation algorithms are used to train the neural network to detect the eye blinks and generate a control signal to select the wanted key from on screen virtual keyboard. The performance of Levenberg-Marquardt is better than the standard one to detect the eye blinks signal.

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الخلاصة

أصبح التعلم الإلكتروني على نطاق واسع أكثر شيوعا على الصعيد العالمي. إن فائدة النظم التفاعلية في التعليم الإلكتروني لا تكمن في تنفيذ المهمة نفسها ولكن في تجهيز الطلبات والتواصل بين نتائج النظام والمستخدم. لذلك فالتعليم الإلكتروني يمكن أن يقدم فرصا كبيرة للطلاب ذوي الإعاقة الذين يمكنهم الوصول إلى التطبيقات المختلفة من خلال قناة بديلة باستخدام اساليب مختلفة كالتفاعل بين الإنسان والحاسوب (HCI).في هذا البحث نحاول أن تستعرض أساليب مختلفة من (HCI) المستخدمة في الإعاقة الحركية وتنفيذ إحدى هذه الطرق باستخدام اشارات تخطيط العين الكهربائي Electrooculography وتحويلها إلى كتابة باستخدام لوحة المفاتيح الافتراضية.